Geologisch-Paläontologisches Institut und Museum
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Berichte - Reports Nr. 1

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Report on cruise no. 1oo b of R. V. "Poseidon", May 7-2o, 1983 - sediments on the Norwegian Continental Margin near the Lofoten Islands.

(Bericht über Fahrt 1oo b des F. S. "Poseidon", 7. - 2o. 5. 1983 - Sedimente am norwegischen Kontinentalrand im Gebiet der Lofoten).

32 S. (pp.), 6 Abb. (fig.), 3 Tab. (tab.),
Kiel, (Juli) 1983

Contents

Summary

Cruise no. 100 b of R. V. "Poseidon" from May 7 to 20, 1983, was made to carry out geological investigations on the continental shelf and upper slope near the Lofoten Islands, Northern Norway. Sub-bottom profiling with 18 kHz and 3.5 kHz echosounder systems and high-resolution side-scanning sonor provided details of bottom morphology and sediment distribution of the youngest sediment cover. Large-size box samples were taken to study the stratigraphy, grain-size distribution, bioturbation structures, patterns of the living populations of benthic foraminifera, and gradients of chemical constituents in the uppermost decimeters of sediment. Sediment cores were obtained from the shelf depressions and from the deeper part of the slope.

On the shelf, the highest thicknesses of Holocene mud sediments were found in Kvalnesdjupet and Vesterdjupet depressions, while in Traena-djupet and the eastern flank of Traenabanken much smaller thicknesses occur. In the latter areas, however, the top layers of the sediments were finer than in the former areas. On the upper continental slope, no Holocene pelitic sediments were found in water depths shallower than about 1000 m. In the northern part of the investigation area coarse relic sediments occur even deeper.

Several sediment slides occur in areas below 700 m water depth which were also found to be covered with coarse relic sediments on glacio-marine clay.

On the outer shelf of the Lofoten Islands, current-indicating bed-forms were found with side-scan sonar.

It may be expected, however, that locally in troughs of the slumping relief fine-grained Holocene sediments are preserved.

1. Cruise program

1.1 Objectives

Poseidon cruise no. 100 is part of a pilot study of Kiel University which is planned to prepare a long-term interdisciplinary project in the Norwegian Sea. In this project it will be investigated how the circulation pattern of the major water masses of the Norwegian Sea and their biogenic production may control sedimentation and generate sedimentary records which are typical for a boreal ocean. From this basic ideas a number of geological questions arose whose answers must be considered as prerequisites for the long-term project. They were the objectives of the second leg of the cruise which are briefly described in the following.

Distribution of Holocene sediments. It is known from the Norwegian continental margin (Holtedahl & Bjerkli, 1982; Vorren et al., 1978, 1983) that the Holocene sedimentation rates are generally very low and that in many places discontinuous or even no sedimentation occurs due to strong current action. However, in the latitudes between 66° and 69° N off and south of the Lofoten Islands, the available sediment maps indicate fine-grained sediments occurring in several topographical depressions on the outer continental shelf and moreover, the continental slope shows sections of relatively gentle slope angles and minor topographical irregularities letting expect the presence of some Holocene mud sediments. In detail, however, little is known on distribution and thicknesses of soft Holocene sediments in this area. For a comparison of the surface distribution of sedimentary parameters with their patterns in the stratigraphic record, Holocene mud sediments of appreciably high sedimentation rates are favorable. Therefore, it was one of the major aims of the cruise to search such favorable localities with sub-bottom profiling and to take eventually cores from Holocene mud sediments.

Morphology. Continental shelf and slope are both highly variable in their relief characteristics in the study area. The detailed knowledge of the morphology may help to understand sediment distribution patterns. However, many morphological features are also of interest as they may reflect both long-term or short-term dynamics of the regional bottom currents. In detail, these features may include differential sediment filling of topographical depressions of various scales or current-induced bedforms as detectable with side-scan sonar which may be evaluated as indicators of sediment transport paths and of the intensity of current action on the sea bed.

Distribution of benthic foraminifers. Benthic foraminifers are of particular interest as indicators of environmental conditions due to different water masses. On the Norwegian continental slope between 62° and 65°N, Skarbø (1980) and Sjerup (1981) related associations of foraminifera species to different water masses, although bio- and thanatocoenoses were not distinguished. In a current investigation (Mackensen, in prep.), living assemblages of foraminifera were distinguished which are related either to the Norwegian Current (NC) on the upper slope or to the homohaline North Atlantic Deep Water. Sampling between 66° and 69°N on the upper slope should help to solve the problem whether this boundary is continuing to the north and if so, in which water depth it may occur. No substantial sampling of living foraminifera was previously done in that region on the shelf. It may be expected to get indications of the influence of the NC water.

Bioturbation. The burrowing activity of benthic animals in the sediment is of particular significance for the basic concept of the study. The influence of this activity on the chemical gradients in the uppermost sediment layer, on the resolution of stratigraphic signals as well as the generation of structures which may be characteristic for the environment are some of the more important aspects of bioturbation. The sampling program of this cruise should provide first results of bioturbation patterns in relation to faunistic observations.

Geochemistry. Many chemical constituents of the sediment may depend on the special environmental conditions provided by the different water masses. Since many chemical compounds, particularly of the liquid phase, are altering shortly after sampling, pore water of the sediments should be sampled on board and a number of chemical determinations of nutrients and organic constituents immediately determined.

1.2 Cruise strategies

The shortness of the available cruise time required a concentration upon a few localities in the investigation area. An adequate selection of such areas was possible on the basis of the existing geological literature on the adjacent shelf and slope areas (Holtedahl & Bjerkli, 1982; Vorren et al., 1978; Gunleiksrud & Lien, 1982) and of unpublished data of the Continental Shelf Institute, Trondheim which resulted in the following study areas.

1) Kvalnesdjupet (Kvalnes Deep). This area is situated west of the southern Lofoten Islands and forms a nearly closed basin separated by a threshold from a valley crossing the shelf (Fig. 1). Its surface forms an isolated occurrence of fine-grained sediment on this shelf section. A survey grid with the sub-bottom profiler and bottom samples was expected to give some control on thickness variation and nature of the sediments.

2) Vesterdjupet (West Deep). This closed bains situated southeast of the Kvalnesdjupet of a similar size and little greater depths and offered itself for comparison with the Kvalnesdjupet.

3) Traenadjupet (Traena Deep). This depression south of the Lofoten Islands is much more extended than the foregoing deeps and forms an extended valley which is open towards the continental slope but without forming a canyon there, on the landward side, it continues to the Vestfjord separating the Lofoten Islands from the mainland. According to sediment maps it is also covered with mud sediments.

4) Continental slope. According to the bathymetric maps, the continental slope shows much variation in steepness and shape in the Lofoten region, although its morphological nature is not known in any detail. Therefore we planned to run survey profiles with the sub-bottom profiler at different places, covering steeper sections as well as shallower ones in order to prepare sampling and coring of Holocene sediments. In particular, the section off the Traenadjupet should be compared with the sections off the southern Lofoten Islands. As the maximum water depth both for coring and for echosounding with POSEIDON is around 1500 m and the transition zones are expected to be much shallower, the profiling was confined to these water depths or little deeper.

5) Traenabanken. In cooperation with Statoil/Stavanger and IKU/ Trondheim, a sampling grid near the drill site NORDRAUG on Traenabanken was planned. The grid covered varying water depths including the transition to the easterly adjacent deep on the inner shelf region. Thus, it represents an area appropriate for comparison with the outer shelf basins.

6) Intermediate shelf areas. The connecting courses between the mentioned investigation areas should offer occasion to run profile lines on "typical" surfaces of the outer shelf zone with echosounder and sidescan-sonar. These areas are largely covered with ice-berg plough marks (Lien, 1982) and were supposed to bear occasionally current-induced bedforms detectable by high-resolution sidescan-sonar.

2. Instruments and methods

2.1 Profiling systems

Profiling systems were used for echosounding, for sub-bottom profiling and for sonographic survey.

2.1.1 18-kHz-echosounder/sub-bottom profiler. This instrument is installed on board ship with two hull-mounted transducers. The recorder (master and slaves) are equipped with continuous digital range shifter ("lift") and a special sediment amplifier system. The echosounder is particularly suitable to penetrate soft (cohesive) sediments above a hard sub-layer. The beam angle referring to the 3 dB level is about 12°. The equipment was also used to observe the bottom contact of the coring devices (Fig.).

2.1.2 3.5 kHz-sub-bottom profiler (EDO Western). As a further means of mapping the younger sediment cover a 3.5 kHz system with a towfish transducer was used. After difficulties with the connecting system, the system worked properly, but nevertheless was little used because it did not show advantages in penetration compared with the 18 kHz echosounder and moreover, the ship's velocity had to be reduced during towing.

2.1.3 Side-scan sonar. Two side-scan sonar systems have been used, working with 100 kHz and 500 kHz, respectively. The 100 kHz system (EG&G Mark I Dual Channel) was towed with a 600 m cable stored on a slip-ring drum using a capstan of a board-installed winch. The 500 kHz towfish (KLEIN Hydroscan) worked with a 1000 m towing cable stored on a ship-installed electrical winch. The high frequency and the related narrow beam angle of 0.2° (3 dB reference) provide a corresponding high resolution which allows to detect, for example, stones of diameters down to 5 centimeters. The range, however, is correspondingly small (about 50 meters on either channel) as is the distance above bottom with towing. For optimum results, the distance must not be larger than 8 to 10 meters. In order to attain the bottom at ship's velocities between 3 and 4 knots, a depressor was suspended below the fish serving also as a safety device. A typical ratio of cable length to water depth was 450 m:150 m.

Because it was felt that the higher resolution could probably more contribute to improvement of the present knowledge than the wider range, after the first run with the 100 kHz system exclusively the 500 kHz system was used. The number of runs had to be restricted, however, due to the low towing velocity and the necessity to select lines of little positive relief differences by reasons of instrument safety.

2.2 Sampling instruments

2.2.1 Gravity corer. Sediment cores were taken with a gravity corer consisting of a 6 m steel pipe, a PVC liner of 12 cm internal diameter, and a variable weight head of 1.5 tons. A pivoting frame connected to a horizontally shifting crane arm allowed to take cores even at considerable rough sea conditions. Due to the coarse-grained and/or stiff sediments to be expected near to the sediment surface, long box corers with large cross-sections otherwise used by the Kiel Geological Institute or piston corers were not taken on the cruise.
The cores were cut into meter pieces and sealed. Only one core was opened on board for chemical investigation.

2.2.2 Large-size Box Corer. For sampling of surface sediments exclusively a large-size box corer (50 x 50 x 50 cm sample boxes) was used. This new, modified device proved as suitable in the Lofoten area with regard to bottom conditions like clay with pebbles and stones, silty sand, or over-consolidated till as well as to handling at rough sea conditions.

The sediment surface of the samples was excellently preserved with few exceptions and was not washed out.

Immediately after recovery, the samples were normally handled and subsampled in the following way:

- photography of surface;
- taking a surface sample of 20 x 20 cm (ca. 1 cm thick) for investigation of living foraminifera populations, stained with Bengal rosa;
- sampling of 4 plexiglass tube cores of 8 cm diameter and 3o cm length: 0-1 cm for Meiofauna, 1-20 cm for collecting of macrofauna 1 mm;
- sampling of 2 plexiglass tube cores for grain-size analysis and documentation;
- sampling of 1 plexiglass tube core for organic geochemistry;
- taking a box sample of 15 x 40 cm or 30 x 40 cm size for sedimentary structures (X-ray graphs);
- various surface and subsurface samples from different samples were taken for investigation by IKU and Statoil;
- the remaining sample was partly washed over a 1 mm sieve and the residual was fixed for investigation of fauna;
- additionally, living fauna was collected from the original sample surface and fixed.

2.3 Navigation and positioning

For navigation, DECCA system was used. The navigation error varied regionally according to the range and intersection relationships of the different chains. On the survey lines, positions were taken at every five minutes. By use of a particular DECCA receiver (RS 4000) coupled with a plotter, this could be achieved mostly automatically.

3. Cruise schedule and station lists

The cruise route and the activities carried out can be gathered from the maps in Fig. 1 and 2 and from the station and profile lists (Table 2 and 3). Table 1 gives a comprised oversight of the activities related to the particular investigation areas.

Due to reasons of organisation and working times, station activities were carried out during day time and profiling measurements mainly during night.

The cruise leg started on May 7, 19 hrs., in Bodø, Norway, and ended on May 20, 10 hrs., in Kiel, FRG.

4. Preliminary results

4.1. Morphology

The continental shelf in the Lofoten area generally shows a rough bottom relief. In a small-scale size of order, the most conspicuous features are ridges and troughs of 5-25 meters of height differences which alternate in an irregular way. These features were interpreted on the basis of sonographic surveys as ice-berg plough marks (Lien, 1982). Most of the shelf area in our investigation area was covered with such features. According to Lien, the plough marks are found down to 450 m water depth. This value roughly coincides with our observations from the continental slope (Fig. 4), whereas in the shelf depressions the maximum depth of plough marks is less. In Traenadjupet, a change in bottom relief type was observed with a break of slope angle at about 380 m (Fig. 3 d). The common rough plough mark relief above that level smoothes in the deeper parts. In Kvalnes- and Vesterdjupet, the deeper parts below 250 m water depth (Fig. 3) did not show plough marks neither on the Pleistocene surface nor in the central parts where it is buried by Holocene sediments. Since in Traenadjupet little Holocene sediment occurs (p. 12), it may be concluded that there primarily less larger plough marks were formed.

In our sidescan surveys, plough marks were found along all lines. The most characteristic feature of these records were the sharp differences in sediment character between troughs and ridges (Fig. 5 and 6). The former showed generally smooth surfaces probably consisting of relatively fine and soft sediments whereas the ridges were covered with strongly reflecting coarse sediments, interspersed with boulders and cobbles of different sizes. The mean maximum size of the boulders was regionally different but did also vary within single survey lines. The plough marks thus indicates a discontinuous - or missing - Holocene sediment layer. The ice plough marks, therefore, may be locally considered as sediment traps in areas where a general sediment cover is lacking.

In a sidescan profile crossing the outer part of the shelf, near the "Egga Morain" ridge (Andersen, 1968), some indications of megaripples and other bedforms were found in the troughs between the ridges (Fig. 5), indicating strong currents parallel to the shelf edge from southwest to northeast.

The relief features of larger scales (Fig. 3) on the shelf are partly due to glacial sedimentation like morainic ridges, but many others apparently are erosional features related to the underlying bedrock structures (Rokoengen & Saettem, 1983).

Continental slope

In the transects north of Traenadjupet, the slope profile is rather irregular. No sharp edge occurs at the transition from shelf to slope, and correspondingly the upper part of the slope is not very steep down to around 600 to 800 m (Fig. 4). However, portions of very steep slope angles were found down to 2000 m water depth. Some of them are nearly vertical and then can be interpreted as slide escarpments (Fig. 4b). Downslope of these escarpments, slump masses are evidenced by typically irregular rough surfaces (Fig. 4c). In contrast to this, the southernmost transects off southern Traenadjupet showed a much simpler slope profile (Fig. 4d). Although the upper slope down to around 900 m water depth still is rather steep, the lower part generally is more gentle there and correspondingly shows sedimentary sub-bottom reflectors parallel to the surface

4.2 Distribution and thickness of Holocene sediments

4.2.1 Kvalnesdjupet. In the Kvalnesdjupet our subbottom profiling (Figs. 1 and 2) resulted in showing a layer of several meters thickness in the deeper parts, being defined by a reflector which is not very strong and sometimes disappears, although obviously the sediment layer is not wedging out then (Fig. 3a). The sampling by box cores and gravity cores showed that the layer consists of silty fine sand in the upper part, whereas the underlying sediment comprising the major part of the core consists of soft clayey-silty mud. The same sequence was observed on the coring localities. It corresponds to similar observations by Holtedahl and Bjerkli (1982) from depressions on the continental shelf off Trondelag (Haltedjupet, Mid Norway). The samples taken at the borders of the Deep (no. 16305 and 16307) at water depths slightly less than 200 m where the sub-bottom reflector no longer occurred, showed only a thin layer of relatively coarse sediment covering glaciomarine clay.

4.2.2 Vesterdjupet. In the Vesterdjupet, the three sampling localities showed stratigraphies quite similar to the cores from the Kvalnesdjupet. Again the sample from the border shallower than 200 m (no. 16301) contained coarser sediments of Pre-Holocene age (gravelly-sandy clay on a gravel layer). On the deeper localities, however, a very fine, silty sand was found without underlying glacial sediments. This holds true also for the core of 5.5 m length recovered from the deepest part in the center of the Vesterdjupet (no. 16322).

4.2.3 Traenadjupet. The picture obtained from the very few samples of the outer Traenadjupet is, of course, far from complete. It seems, however, that there is much less Holocene sediment accumulated than in the deeps described above, that the "mud line" lies considerably deeper and that the sediment filling is asymmetric to the axis of the deep. From the northern border, a very rough plough-mark relief continues down to about 380 m. Little less deeper we were not able to get a sample with the box corer which we attributed to the presence of coarse sediments. A gravity corer taken from the deepest part of the cross section did not gain more than 2.50 m of sediment. Its lower part consists of Glacial till with its top lying only a few decimeters below the surface. On the southern part of the section, in about the same water depth as the sample locality of the northern flank, again a soft sediment layer of only a few decimeters thickness is found. The Holocene sediment is no longer sandy at the top as it was in the Vesterdjupet and Kvalnesdjupet. The sand content seems to be very low generally, but the sediment is characterized by a high content of silica sponge spicules. Holtedahl and Bjerkli (1982) also miss a sandy top layer on the Holocene muds in the deeper parts of Haltedjupet Basin off Trondelag.

4.2.4 Traenabanken. The grid of six samples near the boring rig NORDRAUG is located on the eastern flank of the Traena Bank. It comprises water depths between 221 and 289 m. Most of the area is covered by a rough plough mark relief while in the deeper parts it gets smoother, but without completely disappearing. The 18 kHz record shows a sub-bottom reflector in the deeper parts, marking a top sediment layer of up to 2 m thickness (Fig. 3d). There is also some indication that the layer pursues partly into the plough-mark relief as fillings of the troughs. The box core samples showed in accordance with the echosounder record two sediment types: one consisting of a muddy coarse sand surface layer of a few centimeters thickness covering a grey, fat clay sediment interspersed with coarse sand and pebble component, i.e. a glaciomarine clay with a top layer of residual sediment. The other type consists throughout of a grey, soft silty clay sediment with a brown oxidized top layer. Thus the top layer of the echosounder record can be interpreted as soft Holocene mud.

4.2.5 Continental slope. The three sampling areas from the continental slope (Fig. 1) showed the following results:

(1) The only location where fine-grained sediments of probably Holocene age were found belongs to the southernmost profile where actually a stratified sedimentary sequence is indicated by the echosounder record (Fig. 4).

(2) The thickness of the Holocene on that location is considerable, if the interpretation of Holocene as clayey sediment without dropstones is correct. This is evidenced by core no. 16331 with a length of 6.60 m.

(3) Concluding from above and from the echosounder record of the southern profiles where the stratified top layer wedges out (from below) at 1150 m water depth, little or no Holocene sediment is found on the upper slope of that section as being the case on the northern sections.

(4) The presence of Holocene sediments on the continental slope below about 1000 m water depth seems to depend mainly on the slope angle. In contrast to this, on the upper slope the youngest sediment sequence seems to lack independently of the slope angle. On the middle sampling profile, also on a gentle, even slope (Fig. 4) a top layer of muddy sediments was found lacking above the glaciomarine clay.

(5) Also in a sample taken from a slump mass, in 800 m water depth, glaciomarine clay with a coarse residual layer lies at the surface. It can not yet be concluded, however, that the corresponding slide event was younger than the glaciomarine sediment, since it may form only an uppermost layer draping the slump surface. Likewise, it seems quite possible that in troughs within the hummocky relief of the slumping masses locally Holocene sediment may be preserved. Such occurrences could be located, however, only by a thorough searching with a suitable instrumentation.

(6) All samples from the continental slope besides of the southernmost core showed a coarse residual layer of sand and pebbles on top of a diamict sediment. It may be concluded, therefore, that strong currents affected the slope section north of Traenadjupet, down to at least 1500 m.

4.3 Foraminifera

From each of the box samples, a surface sample of a defined area was taken und preserved with bengal rose alcohol in order to determine the living population of benthic foraminifers. Due to the large size of the box samples and to their largely undisturbed preservation, these samples are considered to yield reliable results in qualitative and quantitative respect. The partially dense sample distribution on the shelf allows to study the influence of the Norwegian Coastal Current on foram distribution. On the continental slope, the depth range of the samples is supposed to be suitable for detecting the boundary between the Atlantic Water and the homohaline North Atlantic Deep Water.

4.4 Macrofauna and bioturbation

Although no faunistic determinations could be made on board ship, the observation of the sediment surface and the sampling of benthic macrofauna allows a few comments on these aspects in combination with some observations on bioturbation.

The sandy-silty muds of the Vesterdjupet and Kvalnesdjupet are intensively populated by suspension-feeding Polychaetes. Decapod crustaceans living in the sediment were also frequently observed, while pelecypods and gastropods besides of scaphopods (Dentalium) are rare and generally of small sizes. Sea urchins also occur sometimes frequently. In spite of this variety of burrowing organisms, only a few bioturbation structures have been observed by bare eye in the vertical section of box samples, including open tubes, typical Decapod burrows (Thalassinoides) and indistinct "mottled structure". However, many additional bioturbation structures may be detected by X-ray examination, and the lacking of any lamination in the sample sections lets expect a high degree of bioturbation in most cases. On the continental slope, by far the most of macrobenthic life has been found as sessile epifauna upon the pebbles and stones occurring on the sediment surface.

4.5 Geochemical investigations

The following chemical constituents in dissolved state have been determined on closely spaced subsamples from 6 box samples (down to 35 cm sediment depth) and 1 gravity corer (down to 325 cm sediment depth): nitrite, nitrate, phosphate, silicate, ammonia, urea, total sugar, and free amino acids. After the separation of the pore water by a filter press, the solid phase of the samples has been dried for further determinations of selected organic constituents.

As a preliminary evaluation of the results, only little differences in the vertical gradient of dissolved components have been observed between Holocene and glaciomarine sediments. Anoxic conditions were not found, although some nitrate profiles showed a slight reduction with increasing sediment depth.

As to be expected, the concentrations of the measured components are about one order of magnitude higher than in sea water. Phosphate, silicate, and ammonia increase with sediment depth, while amino acids and sugar decrease, due to microbial decomposition. This activity is also clearly shown by occurrence of ß-aminoglutaric acid and citrulline. In some cases, an increase of serine was found with increasing depth. It may be noticed that a similar effect had been recently observed in pore samples of Recent sediments from the Antarctic Ocean which was interpreted there as due to solution of diatoms and decomposition of the organic matrix.

5. Acknowledgements

The effective cooperation of Captain H. Schmickler and the crew members of R. V. "Poseidon" is gratefully acknowledged, likewise the untiring technical support given from the persons listed in the participants list. Invaluable help we owe to the Continental Shelf Institute, Trondheim, which provided us with bathymetric maps and other unpublished data for the planning of the cruise.

At essential parts the success of the cruise is due also to the pleasant weather period we enjoyed in those not always pleasant latitudes. Thanks to the responsible authority!

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7. Participants

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GPI - Geologisch-Paläontologisches Institut der Universität Kiel
IfM - Institut für Meereskunde, Kiel
IKU - Institutt for Kontinentalsokkelundersøkelse, Trondheim
GI - Geologisk Institutt, Universitetet Bergen
STO - Statoil, Stavanger

Table 1. Summary of cruise activity. n.m. = nautical miles. Other abbreviations see Tables 2 and 3.

date	inverstigation area	P r o f i l i n g (n.m.) 18kHz	SS100	SS500	3.5kHz	Samples SL	GKG
8.5.	Vesterdjupet	65	3				6
9.5.	Kvalnesdjupet	103					10
10.5.	outer shelf and continental slope B	96					5
11.5.	continental slope B	128					
	outer shelf B	21		5			
	continental slope A	19					
	Kvalnesdjupet					3	
12.5.	continental slope A	59		5		1	3
	outer shelf A	43			18		
13.5.	shelf area B/C	90					
	Kvalnesdjupet	5					
	Vesterdjupet	45		3	11	1	
	Traenadjupet	53				1	
	continental slope C	44					
14.5.	continental slope C	47					5
	Traenadjupet	73			12		
15.5.	continental slope C	36				1	
	outer shelf C	42					
	Traenabanken	67		7			6
16.5.	Traenabanken	26					
	Taenadjupet	43					
	total	1103	3	20	41	7	3

Table 2. : Sample list

no.	Sample type	Date/ time 8.5.83	Water Depth (m)	Position N latitude	Position E longitude	Recovery (cm)	Sediment
16 301-1	GKG	13:47	175	67° 41,7'	11° 02'	19	m-c S
-2	GKG	14:12	175			n.s.	
-3	GKG	14:32	175			8	
16 302-1	GKG	16:00	286	67° 45'	11° 11,3'	33	slf S
-2	GKG	16:22	283			20	
16 303-1	GKG	17:35	235	67° 50,5'	11° 16,2'	11-20	slf S
-2	GKG	18:44	232			n.s.	
		9.5.83					
16 304-1	GKG	10:08	237	68° 15,8'	12° 20,5'	30	sl fS
-2	GKG	10:35	238			32	
16 305-1	GKG	11:22	191	68° 13,9'	12° 18,5'	28	m c p S
-2	GKG	11:44	191			45	
16 306-1	GKG	13:11	240	68° 11,1'	12° 18'	37	sl fS
-2	GKG	13:34	238				
-3	GKG	13:54	238			22	
16 307-1	GKG	15:02	183	68° 07'	12° 07'	22	f m p S
-2	GKG	15:30	185			12	
16 308-1	GKG	16:13	237	68° 02,8'	12° 14,5'	22	sl fS
-2	GKG	16:27	237			26	
		10.5.					
16 309-1	GKG	10:00	263	68° 24'	11° 18,9'	8	c g S
-2		--					
16 310-1	GKG	10:43	432	68° 24,2'	11° 14'	22	c g S+St/ gm C
16 311-1	GKG	11:23	551	68°26,2'	11° 07,1'	11	c g S+St/ gm C
16 312-1	GKG	13:34	695	68°22,2'	11° 07'	43	sl S G/bgmC
16 313-1	GKG	14:33	856	68° 28,5'	11° 05,5'	n.s.	sl S G/bgmC
-2	GKG	14:57	856			13	

Table 2 (cont.). Sample list

no.	Sample type	Date/ time	Water Depth (m)	Position N latitude	Position E longit.	Recovery (cm)	Sediment
16 314-1	GKG	16:06	1000	68°29'	11°02,8'	n.s.	
		11.5.					
16 315-1	SL	10:30	1000	68°26,4'	10°54,8'	n.s.	
16 316-1	SL	16:02	228	68°02,8'	12°14,3'	550	dkg M
16 317-1	SL	17:39	235	68°13'	12°20'	530	dkg M
-2	SL	18:42	235			535	
		12.5.					
16 318-1	SL	10:30	1372	68°52'	12°37,3'	420	fc M/ gm C
16 319-1	GKG	13:45	703	68°50'	12°45'	12	s C+St/ gm C
16 320-1	GKG	15:20	596	68°49,2'	12°48'	15	c g S/gm C
16 321-1	GKG	16:12	500	68°48,2'	12°50,5'	15	c g S/ gm C
		13.5.					
16 322-1	SL	10:22	275	67°47,2'	11°06,2'	550	sl S/ sl C
16 323-1	SL	18:16	481	67°07'	09°27,8'	248	
		14.5.					
16 324-1	GKG	10:24	1072	67°23,1'	08°38'	hand-full	C
16 325-1	GKG	13:18	806	67°20,9'	08°45'	15	c g S/ gm C
16 326-1	GKG	14:19	599	67°19,5'	08°50,5'	12	cg S/sC/fsC gmC?
16 327-1	GKG	14:57	505	67°19,0'	08°52'	little	
-2	GKG	15:37	525			27	sl cg C/gm C
16 328-1	GKG	18:08	367	67°12'	09°37'	n. s.	
-2	GKG	18:34	367			n. s.	
-3	GKG	19:22	369			n. s.	
16 329-1	GKG	20:17	485	67°07,8'	09°29'	10	fs M/ gm C
16 330-1	GKG	21:20	386	67°01'	09°19'	10	fs M/ gm C
		15.3.					
16 331-1	GKG	06:17	1059	67°00'	07°40,8'	5	slM/ gm C
-2	SL	07:25	1057			660	
16 332-1	GKG	15:30	231	66°20,7'	10°10'	10	g M+St/ gm C

Table 2 (cont.). Sample list

no.	Sample type	Date/ time	Water Depth (m)	Position N latitude	Position E longit	Recovery (cm)	Sediment
16 333-1	GKG	16:29	246	66°15,4'	11°11'	43	M St/ gm C
-2	GKG	17:01	256				
16 334-1	GKG	17:46	283	66°10,3'	10°10,4'	16	M/ b gm C
16 335-1	GKG	18:43	289	66°10,3'	09°58'	46	sl M
16 336-1	GKG	19:56	279	66°10,3'	09°50'	12	fsgM/ gmC sl
16 337-1	GKG	20:41	221	66°10,3'	09°45,8'	30	sl S/ gm C

Abbreviations:

f = fine
m = medium
c = coarse   sand
sl = silty
s = sandy
g = gravelly
p = with pebbles
S = sand
C = clay
M = mud
+St = with stones (pebbles + boulders)
gm C = glaciomarine clay
dkg = dark grey
b = brownish
sl S / sl C = silty sand over silty clay

Table 3. Geographical positions of 18 kHz-echosounder profiles. Starting point (S) is equal to end point (E) of the foregoing profile line, if lines are directly connected. Location see Fig. 1 and 2. (SS = side scan sonar)

No. of profile	S/E	latitude (N)	longitude(E)	Remarks
Po100/1	S	67°46,0'	11°27,0'	
Po100/2	S	67°51,0'	11°13,0'	
Po100/3	S	67°54,0'	11°23,0'	
Po100/4	S	67°53,4'	11°38,0'	partly with
Po100/5	S	67°39,5'	10°52,0'	SS 100 kHz
Po100/5a	S	68°14,2'	12°28,0'	
Po100/6	S	68°15,8'	12°22,8'	
Po100/6a	S	68°10,2'	12°10,0'	
Po100/7	S	68°08,0'	12°14,5'	
Po100/7a	S	68°12,4'	12°28,0'	
Po100/8	S	68°10,0'	12°29,4'	
Po100/9	S	68°05,8'	12°16,0'	
Po100/10	S	68°01,5'	12°09,3'	
Po100/11	S	68°06,7'	12°25,0'	
Po100/11	E	68°12,4'	12°13,0'	
Po100/12	E	68°13,0'	12°15,0'	
Po100/12	S	68°08,5'	12°26,8'	
Po100/13	S	68°10,1'	12°29,1'	
Po100/13	E	68°15,9'	12°17,0'	
Po100/14	S	68°07,0'	12°07,0'	
Po100/14	E	68°02,8'	12°14,5'	
Po100/15	S	68°02,7'	12°15,7'	
Po100/15	E	67°55,8'	12°06,9'	
Po100/16	S	67°55,4'	12°08,5'	
Po100/16	E	68°07,0'	12°22,8'	
Po100/17	S	68°06,7'	12°19,8'	
Po100/17	E	68°22,5'	12°23,0'	
Po100/18	S	68°22,5'	12°24,0'	
Po100/18	E	68°39,0'	17°40,0'	
Po100/19	S	68°39,0'	17°40,0'	
Po100/20	E	68°34,1'	11°15,0'	
Po100/21	S	68°21,7'	11°47,0'	
Po100/22	S	68°15,3'	11°27,0'	
Po100/22	E	68°26,8'	10°57,0'	

- Table 3 (cont.) -

No. of profile	S/E	latitude (N)	longitude (E)	Remarks
Po100/23	S	68°30,5'	10°57,0'	
Po100/23	E	68°23,0'	11°20,0'	
Po100/24	S	68°14,0'	11°08,5'	
Po100/25	S	68°26,4'	11°49,4'	
Po100/25	E	68°34,8'	11°27,3'	
Po100/26	S	68°33,8'	11°22,4'	
Po100/26	E	68°25,2'	11°45,0'	
Po100/27	S	68°24,5'	11°40,5'	
Po100/27	E	68°33,3'	11°17,6	
Po100/28	S	68°32,8'	11°13,2'	
Po100/28	E	68°23,8'	11°36,0'	
Po100/29	S	68°23,2'	11°31,5'	
Po100/29	E	68°31,8'	11°09,0'	
Po100/30	S	68°30,5'	11°05,0'	
Po100/30	E	68°22,2'	11°25,0'	
Po100/31	S	68°21,4'	11°20,0'	
Po100/31	E	68°30,8'	10°55,0'	
Po100/32	S	68°29,5'	10°51,0'	
Po100/32	E	68°20,8'	11°15,0'	
Po100/33	S	68°20,0'	11°08,0'	
		68°29,0'	10°54,0'	E SS 500 kHz no. 2172
Po100/34	S	68°22,8'	11°06,0'	
Po100/35	S	68°38,3'	12°09,0'	
Po100/36	S	68°47,8'	11°43,0'	
Po100/37	S	68°52,2'	12°09,1'	
Po100/38	S	68°45,2'	12°34,6'	
Po100/38	E	68°49,0'	12°48,0'	
Po100/39	S	68°49,2'	12°45,0'	
Po100/39	E	68°55,0'	12°27,0'	
Po100/40	S	68°49,0'	12°56,0'	
Po100/41	S	68°40,7'	12°11,0'	
Po100/42	S	68°35,9'	12°58,0'	
	S	68°24,5'	12°24,0'	SS 500 kHz, no. 2173
	E	68°21,8'	12°15,0'	
Po100/43	S	68°20,0'	12°08,0'	
Po100/44	S	68°12,8'	12°21,7'	
Po100/44	E	67°40,0'	10°47,0'	
Po100/45	S	67°35,5	10°58,0'	+3,5 kHz
Po100/45	E	67°52,0'	11°26,0'	

- Table 3 (cont.)

No. of profile	S/E	latitude (N)	longitude (E)	Remarks
Po100/46	S	67°37,2'	10°52,8'	SS 500 kHz no. 2174
Po100/46	E	67°35,2'	10°58,0'	
Po100/47	S	67°35,0'	10°55,0'	
Po100/47a	S	67°14,5'	09°41,5'	
Po100/47a	E	67°05,8'	09°26,0'	
Po100/48	S	67°00,7'	09°27,8'	
Po100/49	S	66°45,7'	08°23,8'	
Po100/50	S	67°04,0'	07°23,0'	
Po100/51	S	67°16,8'	07°50,0'	
Po100/52	S	67°06,0'	08°28,0'	
Po100/53	S	67°18,4'	08°55,0'	
Po100/53	E	67°28,5'	08°15,0'	
Po100/54	S	67°19,0'	08°52,0'	
Po100/54	E	67°12,0'	09°37,0'	
Po100/55	S	67°00,6'	09°19,5'	+ 3,5 kHz
Po100/56	S	67°01,7'	09°44,7'	
Po100/57	S	67°09,8'	09°06,0'	
Po100/58	S	66°55,0'	08°42,0'	
Po100/59	S	67°07,4'	07°48,0'	
Po100/60	S	66°59,0'	07°45,0'	
Po100/61	S	66°14,1'	10°00,0'	SS 500 kHz no. 2175
	E	66°14,1'	10°11,5'	
Po100/62	S	66°14,1'	10°51,0'	
Po100/63	S	66°42,5'	11°07,0'	
Po100/64	S	66°52,1'	10°37,0'	
Po100/64	E	66°45,0'	10,23,0'	

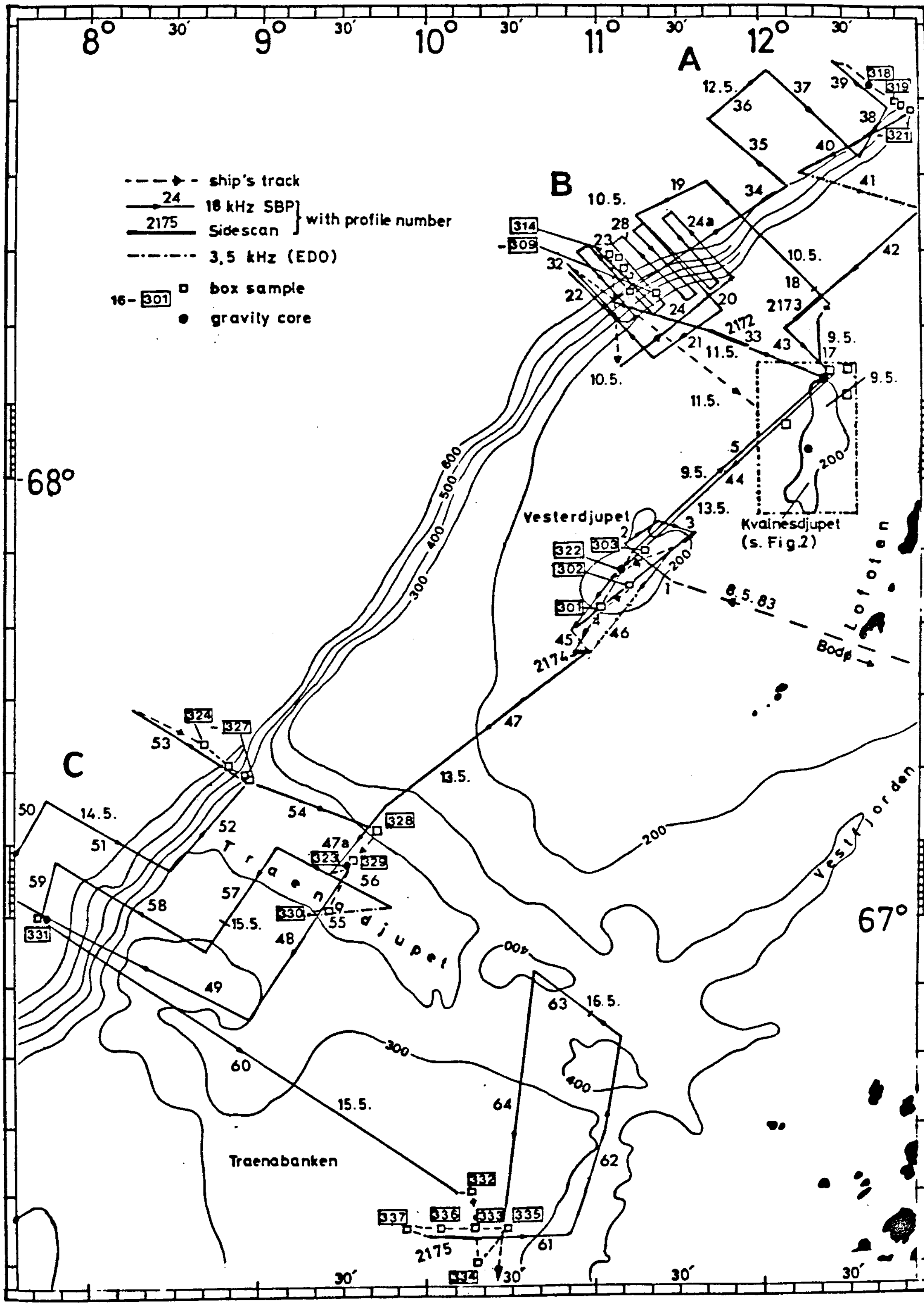


Fig. 1. Study area with cruise tracks and sample localities of Poseidon cruise 100 b. Depth contours in meters.

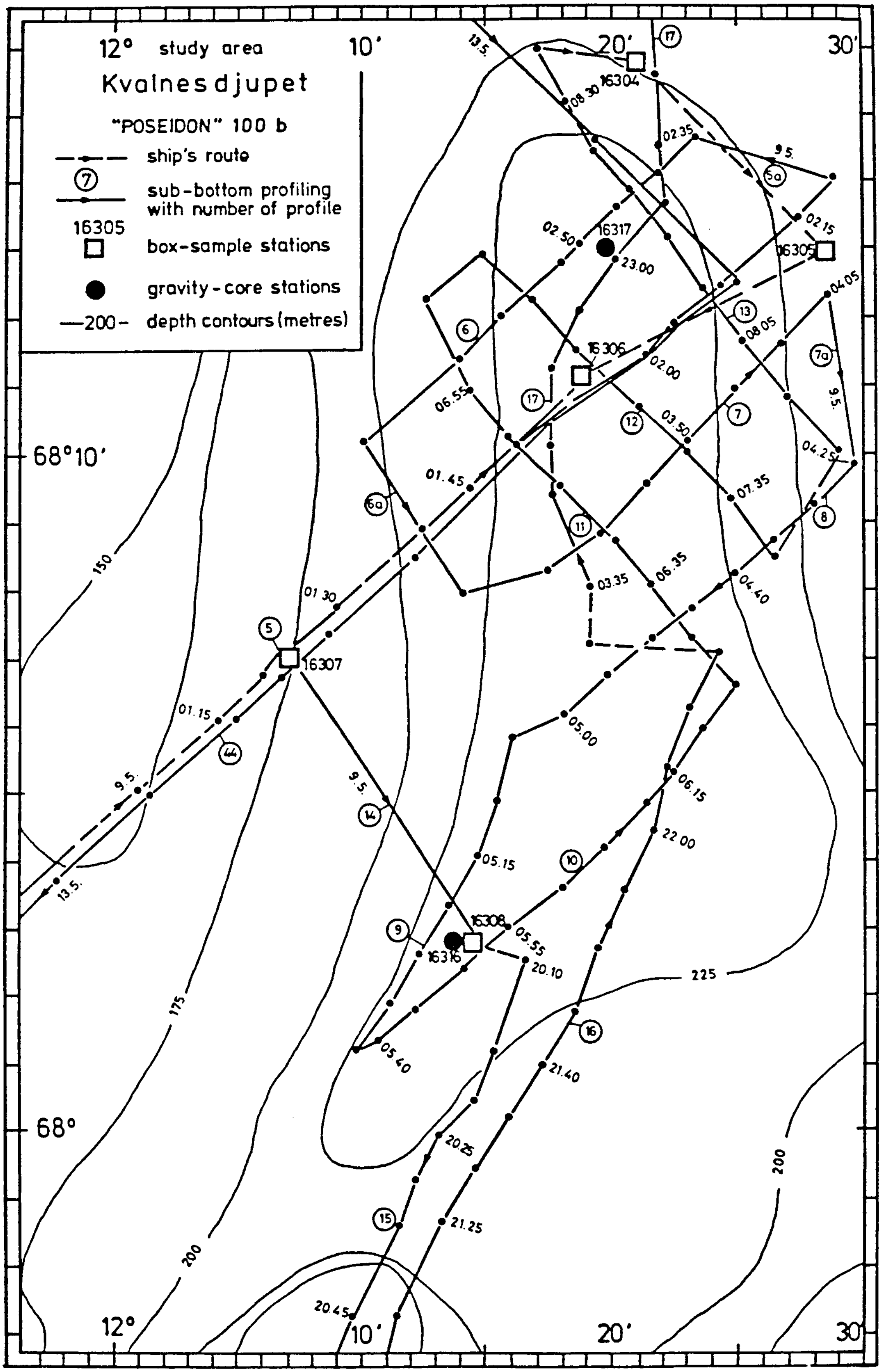
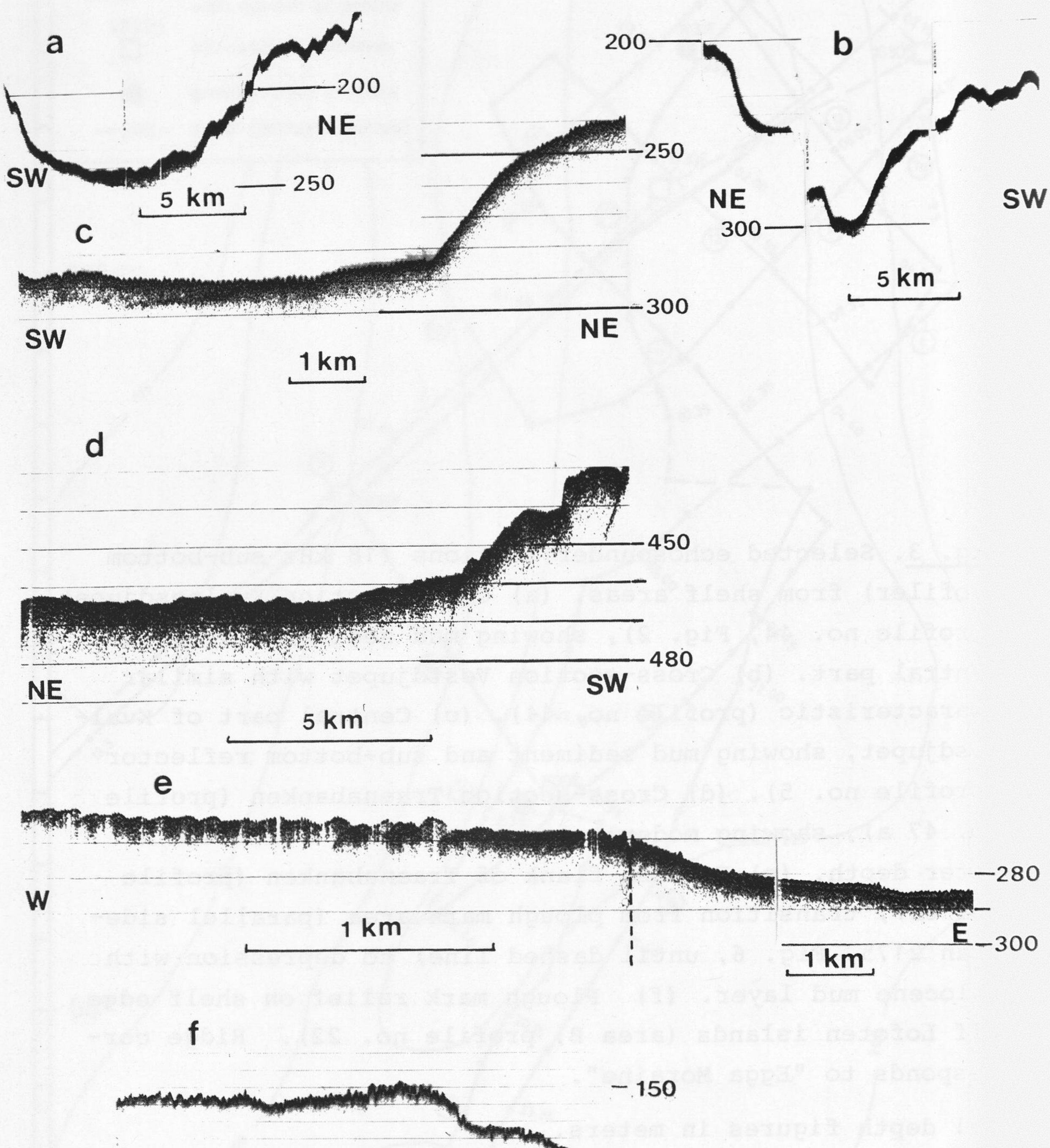


Fig. 2. Study area Kvalnesdjupet.

Fig. 3. Selected echosounder sections (18 kHz sub-bottom profiler) from shelf areas. (a) Cross-section Kvalnesdjupet (profile no. 44, Fig. 2), showing mud sediment layer in central part. (b) Cross-section Vestdjupet with similar characteristic (profile no. 44). (c) Central part of Kvalnesdjupet, showing mud sediment and sub-bottom reflector (profile no. 5). (d) Cross-section Traenabanken (profile no. 47 a), showing moderately rough relief below 460 m water depth. (e) Eastern flank of Traenabanken (profile no. 63), transition from plough mark area (parallel side-scan 2175, Fig. 6, until dashed line) to depression with Holocene mud layer. (f) Plough mark relief on shelf edge off Lofoten islands (area B, profile no. 22). Ridge corresponds to "Egga Moraine".

All depth figures in meters.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NE
SW
5 km
250
b
200
NE
300
SW
5 km
c
250
300
SW
NE
1 km
d
450
480
NE
SW
5 km
e
280
300
W
1 km
E
1 km
f
150
200
SE
NW
5 km

Fig. 3

Fig. 4. Selected echosounder sections (18 kHz sub-bottom profiler) from continental slope. (a) Upper continental slope area B (fig. 1), profile no. 29, buckling relief in lower part due to slumping (?), (b) Profile no. 32 (in the same area), showing slope angle increasing with depth. (c) Northernmost profile (no. 39, area A), showing highly variable slope angle and slumping area at bottom . (d) Southernmost profile off Traenadjupet (no. 49). Sub-bottom reflectors below 1000 m water depth (arrow).
All depth figures in meters.

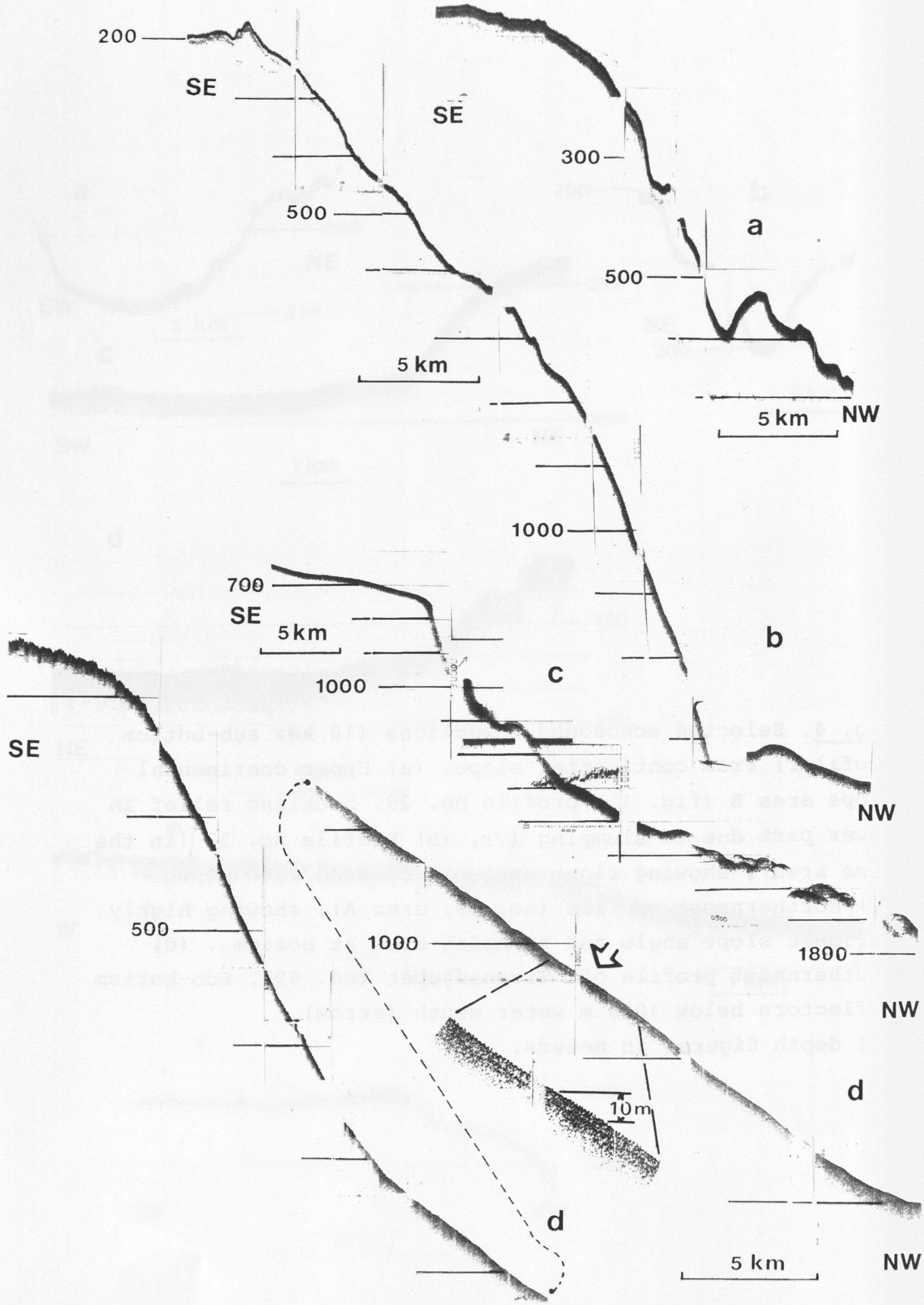
200
SE
SE
300
500
a
500
5 km
5 km
NW
1000
b
700
SE
5km
1000
c
SE
NW
500
1000
1800
NW
10m
d
d
5 km
NW

Fig. 4

Fig. 5. 500 kHz sonograph of plough-mark area outer shelf off Lofoten islands (western part of profile H-2172, Fig. 1). (a) Boulder of 0.8 m diameter. (b) Current-indicating comet marks, arrow in current direction. (c) Crests of megaripples in troughs between ridges.

Fig. 6. 500 kHz sonograph southeast of Traenabanken (profile no. H-2175), showing plough-mark relief. (a) Boulder group of 3.6 m maximum height.

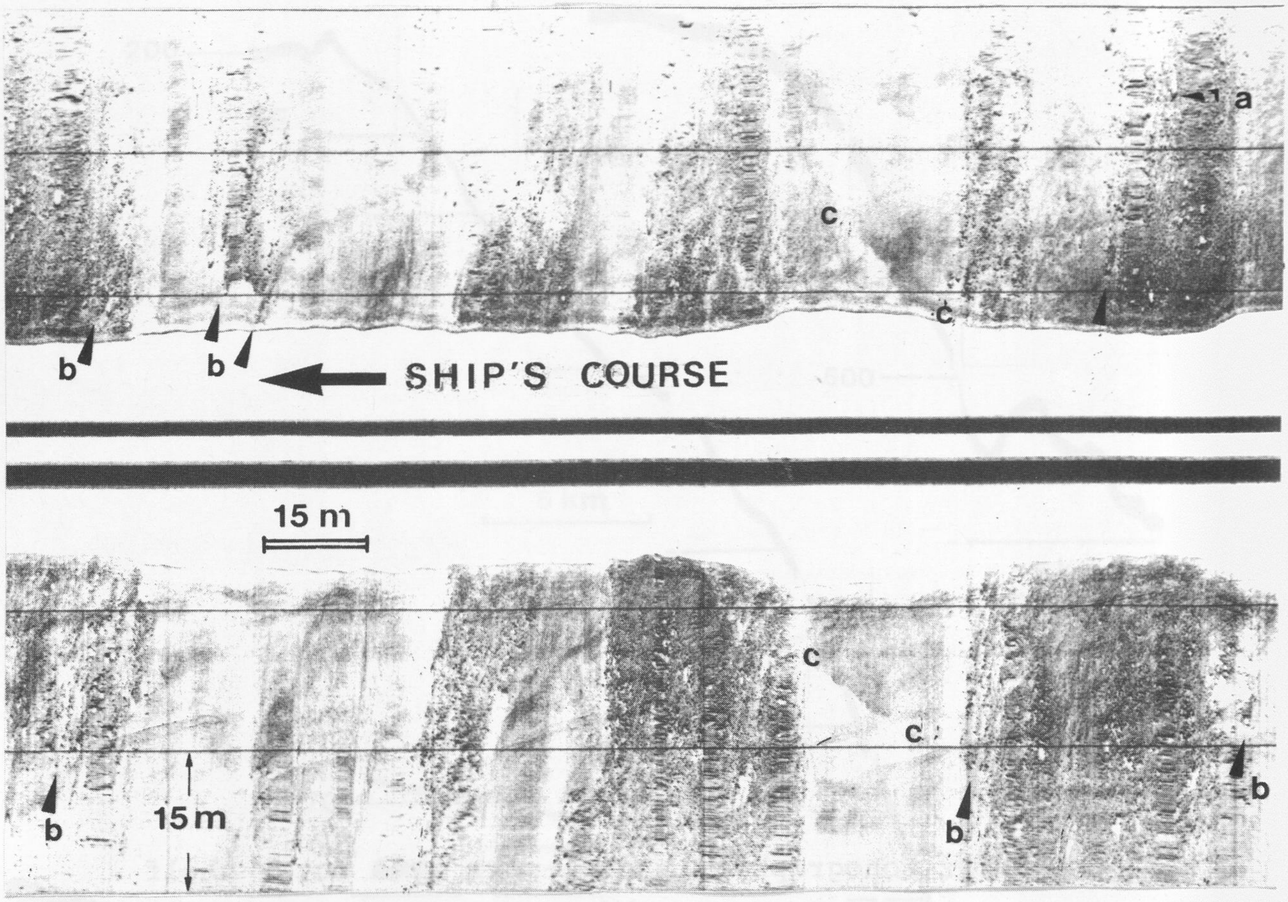

Fig. 5

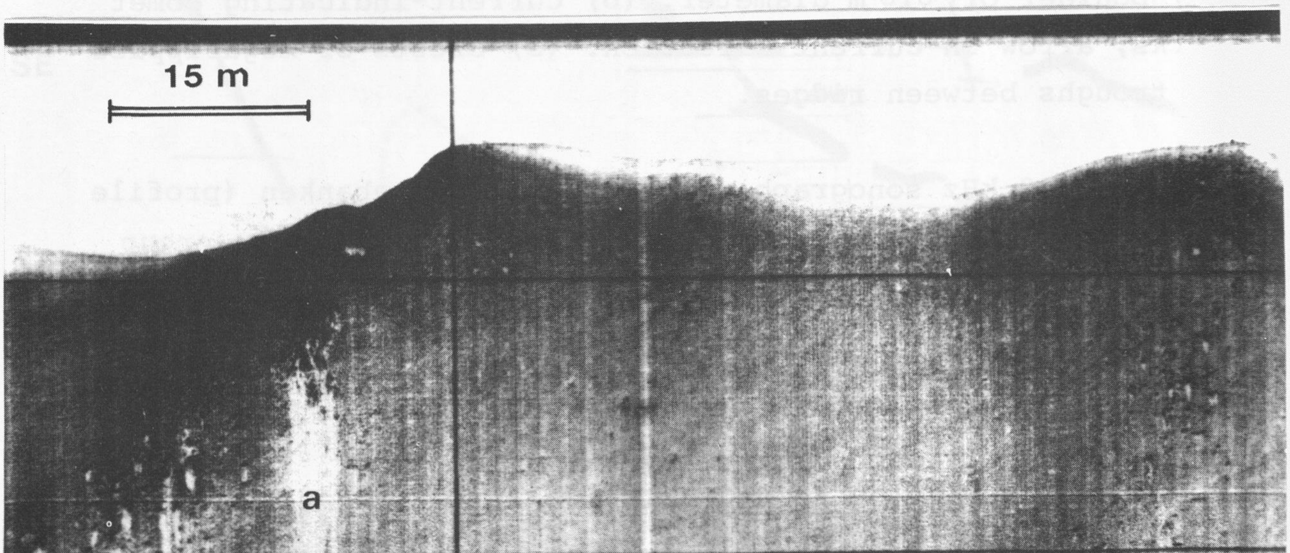

Fig. 6